Quantum measurements are physical processes. Comment on "Consciousness and the double-slit interference pattern: Six experiments," By Dean Radin et al. [Physics Essays 25, 2 (2012)]

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The validity of the assertion that some recent double-slit interference experiments, conducted by Radin et al., would have tested the possible role of the experimenter's mind in the collapse of the quantum wave function, is questioned. It is emphasized that quantum mechanics doesn't need any psychophysical ingredient to explain the measurement processes, and therefore parapsychologists shouldn't resort to the latter to support the possibility of psychokinesis, but search for more convincing explanations.

La validité de l'affirmation selon laquelle certaines expériences récentes avec un système optique de double fente, conduites par Radin et al., auraient testé le rôle possible de la conscience dans la réduction du paquet d'onde en mécanique quantique, est disputée. On souligne que la mécanique quantique n'a pas besoin d'un ingrédient psychophysique pour expliquer les processus de la mesure et que par consequent les parapsychologues ne devraient pas recourir à ce dernier pour soutenir la possibilité de la psychokinèse, mais chercher des explications plus convaincantes.

Keywords: Quantum measurement problem; Hidden variables; Hidden-measurements approach; Mind-Matter Interaction; Consciousness.

In a recent paper, Radin et al. [1] have presented a series of interesting interference experiments which, I quote, were "used to test the possible role of the experimenter's mind in the collapse of the quantum wave function." The results of these experiments are certainly challenging for the dominant materialistic/physicalistic paradigm, as many other experiments testing the effects of human intentionality on physical systems also are (see for instance the references cited in [1]). It is however not the scope of the present note to enter into the highly controversial and lively debate of "believers VS non-believers" [2], nor to enter into the specificities of the protocols used by Radin and collaborators in their experiments, for instance to evaluate if biases could be identified, that would allow for a different (non-psychophysical) interpretation of the obtained results.

As a matter of intellectual transparency, I'd like to state that, contrary to today's leading view (at least in scientific circles), I'm not at all against the hypothesis of the existence of a subtle mind-matter interaction mechanism. Therefore, I am personally favorable to experiments like those conducted in [1]. To say it all, my propensity is also to corroborate the interpretation of the results in terms of an objectively real psychophysical effect, whose origin and action modalities are still to be elucidated. This also because, as is the case for a relevant number of human beings, scientists included, I was able to personally and lucidly experience, in many occasions of my life, so-called psi phenomena. Thus, although I'm perfectly aware that first person subjective experiences do not easily translate into more objective statements, considering nevertheless the considerable amount of first person and third person data today available about psi phenomena, it is certainly licit not only to expect a more systematic investigation of them in academic ambits, but also to have more theoreticians from different disciplines paying an effort to construct explanatory schemes that would go beyond the often too simplistic hallucinatory-like, fraud-like, and/or bias-like accounts which are often provided by those who are a priori skeptics.

The above is important to say not only because it is still a taboo to overtly speak about these topics in institutional circles, despite a great number of scientists acknowledge in private conversations the possibility of psi phenomena, and it is definitely time to break this irrational taboo, but also in order to correctly contextualize my point of criticism about the interpretation provided in [1], which doesn't originate from a personal idiosyncrasy toward the controversial psi phenomena as such.

My disagreement is about the position of Radin et al. regarding the fact that the results they have obtained would appear to be consistent with a consciousness-related interpretation of the quantum measurement problem, and that their double-slit interference experiments would have somehow tested, and confirmed, the "consciousness collapse hypothesis." It is the purpose of the present note to try to explain the reasons of my disagreement.

First of all, let me observe that the motivation of the authors in choosing a double-slit interference system for their experiments of psychokinesis is clearly the one finding a situation that would be more closely related to the quantum level of reality, as opposed to more general PK experimental situations, not necessarily exploiting

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pure quantum systems, like for instance classical systems highly sensitive to initial conditions, or systems where such a direct relationship would be less evident. However, if the human PK-effect is a real effect, then it is natural to assume that the basic physical mechanism explaining its emergence would be always the same, independently of the nature (classical, quantum or intermediate) of the physical system which is chosen as an object of the experimentation. And since quantum physics is one of our most fundamental physical theories, if the quantum wave function collapse could really be triggered (in a selective way) by a human mind, then one can easily infer that, *mutatis mutandis*, this same psycho-based activation mechanism should also be at the origin of PK-effects on classical (non-quantum) objects.

Having said this, it is however important not to fall victims of a too hasty reasoning. It is clear that within present-day understanding of physics the only mechanism that one can possibly invoke to theoretically support the existence of a PK-effect (and of other psi phenomena, like telepathy and clairvoyance) is an interpretation of the quantum observer effect as a pure mind-driven effect of *actualization of potential properties*. But the fact that a psychophysical interpretation of the wave function collapse appears to be the only place where a PK-effect might possibly be explained within the framework of modern physical theories, certainly doesn't imply that if a PK-effect is evidenced in experiments with quantum systems (like photons in double slit apparatus) this would mean that the experiments would have confirmed the role of consciousness in the quantum measurement process, as the authors in [1] appear to suggest, more or less explicitly.

Actually, thinking in this way, or hinting to such a possibility, can only bring more misunderstanding to the already highly controversial issue of the PK-effect, as well as on the possibility of reaching a more mature understanding of what von Neumann's "Process 1" are all about: a simple physical *instrument effect*, and not a psychophysical effect! What I'm here stressing is that it is highly improbable, considering what we today know about quantum mechanics (and that the founding fathers didn't know), that the theory would ever need the intervention of the consciousness to explain the measurement process. Also, in the highly unlikely circumstance that such an intervention would nevertheless be required, the way consciousness would be involved in the measurement process is in an case very different from what is actually needed to explain an *intention-based* PK-effect, able to alter the statistical predictions of quantum theory (von Neumann's Processes-1 cannot be used to select a preferred outcome).

Let me start by recalling the reason why, in the first place, physicists started discussing about consciousness in quantum mechanics, as a possible ingredient to explain quantum measurements (i.e., experimental observations). As is well known, everything started with a famous reasoning of von Neumann [3], who observed that there are no specifications in the theory regarding how to distinguish and separate the quantum observed system from the observing apparatus (such a separation, which remains arbitrary in the theory, is sometimes called the *Heisenberg's cut*). Therefore, the (macroscopic) measuring apparatus can in principle also be described in conjunction with the measured system, as a purely quantum system, obeying a continuous unitary evolution (von Neumann's "Process 2"). According to the theory, the observed system plus the measuring apparatus can also be described as a system in a superposition state, and to reduce the superposition one needs to introduce an additional measuring apparatus; but again, this additional apparatus can also be described quantum mechanically, in combination with the two previous systems, and therefore be considered as being in a superposition state. Adding new measuring apparatus of course cannot help in breaking such a virtually infinite chain of measurements. Indeed, to do so, one needs to introduce an entity of a different kind, which would not be subject to the rules of quantum mechanics. But since quantum mechanics is about general physical systems, this very special entity should be, in a sense, non-physical (or extra-physical), and here is where the idea of a non-physical consciousness (or mind, the two terms are used equivalently in this context) able to cut the above "chain" enters into the physics' discourse.

Over time, this highly speculative hypothesis has been reconsidered by a number of (often prominent) authors, as rightly emphasized in [1]. However, as I will explain, such hypothesis is not any more justifiable today as an explanation of the quantum measurement problem, and so neither can it be invoked as a credible explanation for the controversial mind-matter interaction mechanism which would be behind the PK-effect.

An experimenter in a physics' laboratory usually does not "think about specific outcomes of the experiment." Experimenters don't focus their attention upon them, trying to obtain a certain result, instead of a certain other, at least not consciously. All what they do, at a certain moment, is to *take cognizance* of the results of the experiment, by reading for instance the data on a monitor, or on whatever other recording apparatus. This is an important remark because, even assuming that the consciousness would have a role to play in the measurement process (which is highly improbable, as we will make clear in the sequel), such a role doesn't require anything more than just the act of taking knowledge of the results, i.e., having a *conscious representation* of them. This appears to be sufficient to break the hypothetical virtually infinite chain of measurement processes described by von Neumann, as is also clear that no experimental physicist receives a special mental training in order to perform laboratory experiments, and that no physicist so far has ever directly observed a superposition state.

Also, as it was recently lucidly pointed out by Yu and Nikolic [4], if the role of the consciousness would be instrumental in producing the collapse of the wave func-

tion, then each time there would be a collapse there should also be a conscious representation of the corresponding outcome. But this also means that the collapse of the wave function should actually never occur if the corresponding result has not been duly registered by a conscious observer. Now, an analysis of the already existing empirical results, for instance in typical "which-path experiments," already strongly suggest that a conscious access of the information about the outcome of an experiment is not a necessary condition for the collapse of the wave function to occur. In other terms, it appears that in consideration of the already available experimental evidence, the hypothesis of a link between the human mind and the collapse of wave function would have been already falsified in a number of occasions.

But independently of the pertinence of the analysis in [4], which although certainly needs to be completed it already casts strong doubts on the pertinence of the consciousness' hypothesis, there is in fact a much more important reason for abandoning it: *we simply do not need it!* Not in the sense that, following David Mermin's famous provocative injunction, we should only "shut up and calculate!" and avoid getting involved in whatever metaphysical speculation, but in the sense that: we don't need it to explain von Neumann's Processes-1, and the mechanism producing the transition from probabilities to actualities, during a quantum measurement.

Before explaining why we don't need any psychophysical process to explain discontinuous Processes-1 (also called quantum jumps, or R-processes), it is important to highlight the reason why von Neumann's ideas are still today debated among physicists and maintain a certain number of devotees (as the publication of the paper of Radin et al. in a physics journal actually demonstrates). This is because the majority of physicists cultivate the idea that quantum mechanics is to be considered, in one way or another, a complete theory of the physical reality, so that von Neumann's reasoning, although quite embarrassing, would in a sense be inevitable. However, the fact that quantum theory doesn't indicate where to put the separation between the observed system and the observer system (the missing Heisenberg's cut) and, more importantly, how to separate them, should lead at least to a certain suspicion regarding its alleged completeness.

In fact, the incompleteness of quantum theory is not at all a hypothesis, as nearly thirty years ago the Belgian physicist Diederik Aerts has rigorously proven that the conventional (Hilbertian) quantum formalism is inadequate, structurally speaking, to describe *experimentally separated* physical entities. [5, 6] This structural shortcoming of the quantum theory is quite severe, if one thinks that to give a proper sense to the distinction between the observer system and observed system, it is obviously necessary to separate them, in the sense that during an observational process the observation system should initially be separated from the observed system, then the two systems should connect in some way, to allow the measurement per se to take place, and finally, at the completion of it, they should separate again. But such a process of separation-connection-separation is not at all describable within the too restricted Hilbertian framework of conventional quantum mechanics, hence the need for the introduction of an immaterial entity, in order to "solve" the measurement riddle.

Let us observe that the incompleteness proof of Aerts has been derived thanks to a theoretical approach to the description of physical systems which is much more general than conventional quantum mechanics, which prior to considering the specifications of the microscopic world tries to identify what are the "rules of the game" when a physicist investigates in all generality a physical system. In this more ample conceptual and mathematical framework, known as the *Geneva-Brussel* operational approach [7–9], the conundrum of the quantum measurement has found a very clear and convincing solution, in the sense that the mysterious origin of quantum probabilities has been fully clarified and the quantum observer effect explained as a "down to earth" *instrument effect*.

More precisely, this has been done in the ambit of a specific analysis called the *hidden-measurement approach*, [9–11] (See also [13, 14] and the references cited therein). Now, considering its great explanatory power and conceptual simplicity, as well as the fact that, surprisingly, it is still very little known, let me briefly describe here below what it is all about.

The idea at the basis of the hidden-measurement approach is that quantum probabilities, like all the probabilities that physicists have ever met before the advent of quantum physics, just correspond to a measure of our *lack of knowledge* about "something" associated to the experiment under consideration. This "something" has been typically associated in the past to the properties actually possessed by the system, but not explicitly known by the investigating scientist. These hypothetical unknown elements of the micro-reality have been called *hidden variables*, and it was long believed that if the values taken by these hidden variables could be explicitly known, then the real state of a microscopic system could also be fully determined, and probabilities wouldn't be any more necessary to predict the outcomes of whatever quantum measurement. In other terms, according to the historical approach to hidden variable theories, quantum physics was to be considered incomplete because of its failure in describing the real state of a microscopic entity, which wasn't entirely specified by the given of the wave function.

The hidden variable hypothesis is of course a very natural one, and if proven correct it would provide a complete solution to the measurement problem. Clearly, everybody would agree that a psychophysical reasoning à la von Neumann would become totally meaningless in case the hidden variables hypothesis would prove its soundness, in the same way as it would be totally meaningless to require the intervention of a mind-matter interaction to explain the relationship between thermodynamics and statistical mechanics. However, as is well known, hidden

variable theories have encountered important obstacles: the celebrated No-Go theorems. [15–17]

But in the end, the apparently insurmountable obstacle of these impossibility proofs has been bypassed by Aerts' hidden-measurement approach, thus allowing to still understand quantum probabilities as *epistemic* statements, i.e., as quantities measuring our lack of knowledge about "something" pertaining to the experiment under consideration, so that we don't need to resort to any "mental trigger" to explain the passage from probabilities (potentialities) to actualities. But then, since this "something" can't be associated to variables specifying the state of the system, as this would be generally forbidden by the mentioned No-Go theorems, what is it associated with? The answer is amazingly simple: they are associated to the measurement process itself, i.e., to the measuring interactions that take place between the system (S) and the measuring apparatus (M).

More specifically, when S and M are allowed to interact in a typical quantum measurement, there is more than a single measuring interaction potentially available. To describe this situation, one can introduce a hidden variable λ, and to each λ associate a specific measurement interaction I_λ, giving rise *deterministically* to a specific outcome. Since the way interactions I_λ are selected during a quantum measurement process is totally beyond the control power of the experimenter, and considering that different interactions will generally produce different outcomes, it follows that the experimenter (i.e., the observer) is not in general in a position to predict in advance the outcome of a measurement, but just predict it in probabilistic terms.

In fact, one can show that quantum probabilities correspond to the situation where this lack of knowledge about which specific deterministic interaction I_λ is actually selected during a measurement is *maximum*, whereas the classical regime corresponds to the opposite situation where this lack of knowledge is *minimum*. Interestingly, in between these two limit situations one can also describe more general ambits, of *intermediate knowledge*, corresponding to new quantum-like structures, neither purely classical nor purely quantum.

Of course, it is not the purpose of this note to enter into the technical developments of this approach, and we refer the interested readers to the mentioned papers and the references cited therein. What is important to emphasize here is that one can rigorously prove that the hidden-measurement mechanism is perfectly able to reproduce the typical *non-Kolmogorovian* structure of the quantum mechanical probability calculus, and therefore provides an exhaustive solution to the longstanding measurement problem. [9–11]

What is also important to stress, particularly in relation to the theme of this note, is that the selection of a specific deterministic interaction I_λ, which gives deterministically rise to a specific outcome during a measurement, doesn't require the intervention of any psychophysical effect: it is in fact just the consequence of a very physical *symmetry breaking process*, due to the presence of fluctuating factors in the experimental context.

A very important feature of the hidden-measurement approach (and of the more general conceptual framework into which it enters, known as the *creation-discovery view* [11]) is that it also allows to fully clarify the nature of the *creation aspect* which is inherent in the quantum mechanical *observer effect*. It is indeed certainly correct to affirm that during a typical quantum measurement the observed property is literally created by the measurement itself – and in that sense we could say that the hidden-measurement approach is not an observer-free approach – but such a creation aspect cannot be traced back to a mind-matter interaction mechanism: it is simply the result of the above mentioned purely physical symmetry breaking process, causing the selection of a specific interaction I_λ in an unpredictable way; exactly in the same way as when for instance, by pushing on a cylindrical stick vertically planted on the ground, we cause it to flex in an a priori unpredictable direction, and by doing so we break the initial rotational symmetry and literally *create* a direction that wasn't present prior to the experiment. In a nutshell: quantum physics does describe an observer effect, which is a creation effect, but the mechanism subtending this effect has nothing to do with a mind-matter interaction. [14]

Of course, the hidden-measurement explanation is not the only possible explanation for the measurement process, but it certainly constitutes a very general and conceptually clear scheme, which has the advantage of demystifying much of the mystery, and false mysticism, which has been created over the years around the issue of quantum measurement. In that sense, it is not only important as a physical and mathematical theory per se, but also in relation the PK controversy, as it unmistakably shows that the presumed *ontic* character of quantum probabilities is totally unfounded, and therefore the theory doesn't present any causal opening in which a mind element could be accomodated.

This is important because some of the best known and widespread explanations of the measurement problem, which avoid a psychophysical argument "à la von Neumann," require in counterpart some additional, more or less exotic, ingredients, which in the end render the whole explanation not much more credible than the psychophysical one (this is at least the opinion of this author).

Indeed, one may rightly ponder if it wouldn't be after all more convincing to "solve" the measurement problem by evoking the influence of an "abstract ego" (to use von Neumann's terminology), if the alternative is the one of having to postulate the existence of non-denumerably infinitely many, increasingly divergent and non-communicating parallel quantum worlds, in which all possible quantum outcomes would be realized, following the quite trendy *many worlds (relative state) interpretation*. [18, 19] At least, the first solution is much more parsimonious from the Occam's razor point of view.

Let us consider for instance the apparently down-to-earth approach to the measurement problem called *decoherence theory*, [20] which can be considered as a modernized version of Bohr's interpretation. As Radin et al. rightly affirm in their paper, such a theory is not without problems, despite being probably today the most commonly adopted "explanation" for the measurement issue. Let us briefly recall here what it is all about. Decoherence describes the disappearance of superposition in the system and measuring apparatus as a consequence of their unavoidable interaction with the environment. According to this view, even though superposition doesn't totally disappear, it gets almost instantaneously delocalized into the environment, so that for all practical purposes the system is (approximately) describable by a mixture., i.e., by an (almost) diagonal reduced density matrix.

The problem of course is that this is just an approximate description, although a very good one, and that strictly speaking one still needs to explain how the global wave function, which gets increasingly entangled with the environment, will finally collapse. Everything happens *as if* the state describing the system could be interpreted to represent a classical distribution over specific values of the measured observable, but the crucial point is that since the mixture describing the system is an improper one, in the sense that it is only an approximate mixture, one is not allowed to say that the outcome of the measurement would be predetermined. In other words, the superposition of different outcomes still exists, as the coherence has just been "diluted" into a larger system. And this is the reason why the non-superficial adherents to decoherence theory are compelled to complete their explanatory scheme by resorting to a many worlds picture.

The difficulty here is that within the narrow limits of the Hilbert space structure of conventional quantum mechanics (and of its tensor product) one cannot describe the process of complete decoherence which would be induced by the separation of the measured entity from the measuring apparatus (or from the environment). Indeed, this separation process, and the symmetry breaking it involves, causing the selection of a specific outcome, can only be described in the ambit of a more general mathematical and conceptual framework, like the one which was derived over the years by the Geneva-Brussel school. [7–9] In other terms, the failure of decoherence theory in properly describing the measurement process is due to the already mentioned incompleteness of conventional quantum theory, which makes the description of a separation process, which must be part of any meaningful measurement process, impossible.

So, it appears that also the proponents of the most matter-of-fact orthodox "explanations" of the measurement problem are forced, for questions of consistency, to call for the existence of bizarre additional entities, like multiple words, and this to my opinion is one of the reasons why a consciousness-based interpretation is still so in vogue today, despite being perfectly unnecessary and therefore unfounded. This also because, apart from the new orthodoxy of decoherence theory, the many other proposals which are today available in the large market of quantum interpretations appear to be also impaired either by internal inconsistency or by external implausibility.

Of course, I cannot review and evaluate here all the existing interpretations, which are extremely numerous. However, let me just comment about one which was also mentioned by Radin et al. in their article, in addition to decoherence: the so-called *knowledge picture*, or *epistemic view*, which has a quite long tradition but actually became much more widespread with the advent of quantum information theory. According to this interpretation, the quantum wave function would correspond to our "state of knowledge" about the system under consideration, and not to an objective description of the real state of the system. Accordingly, the collapse of the wave function would only describe our sudden acquisition of knowledge about the system, and nothing would actually happen to the latter during a quantum observational process (only the state of our knowledge changes, not the state of the system).

This interpretation, however, cannot be entirely correct, as is clear that if it would, then there would be an underlying level of reality – the objective level about which we gain knowledge – which is not describable by the wave function, so that in the end the "epistemic view" is nothing but an expression of a hidden variable theory (with the hidden variables referring to the state of the system), but such a theory should be in principle describable by a classical Kolmogorovian probability theory, and not by a quantum non-Kolmogorovian probability theory [12], and has to confront with No-Go theorems.

I could certainly go on for a certain time identifying all the unusual ingredients that physicists were compelled to introduce in their countless proposals for a solution of the quantum measurement problem, and this is the reason why I believe that the hidden-measurement approach introduced by Aerts, nearly thirty years ago, is so important in the process of a complete demystification of this controversial subject, and that it is particularly unfortunate this very simple and convincing solution is still so little known among physicists.

One of the reasons for its lack of notoriety is probably the fact that the approach emerged from a very general, operational and axionatic analysis of physical systems, employing sophisticated mathematical and conceptual tools, in which ordinary quantum mechanics, as well as classical mechanics, arose as special cases of more general structures. Now, apart from the trouble of acquiring new mathematical and conceptual tools, a main difficulty in obtaining a wider acceptance of this approach has probably been the already mentioned preconception, held by many physicists, that an Hilbertian structure would be more than sufficient to describe all of reality, according to the belief that ordinary quantum theory is

a complete theory of reality.

So, one of the motivations in writing this note is to promote a greater spread of these results within the scientific community, not only the one of physicists, but also of parapsychologists, so that the former can address the measurement problem in a much more disenchanted way, and the latter can address the problem of explaining the psi phenomena without improperly appealing to quantum physics, as in ultimate analysis quantum physics is only about physical entities, not about mind-matter interactions.

Having said this, let me emphasize once more that, independently of the fact that we don't need von Neumann's psychophysical effect to explain quantum measurements, even assuming for a moment that such a psychophysical explanation would be required – although it is not – we nevertheless can't use it to explain the functioning of the PK-effect. Indeed, one would need for this a mechanism explaining how the subject in a typical PK-experiment would be able to alter the quantum probabilities, by focusing her/his attention on the system in a certain way. But such an influence of the mind of a human observer over a quantum system, causing its probabilities to *deviate* from what is predicted by quantum mechanics, obviously, by definition, cannot be understood by invoking a mind-driven collapse of the wave function, as such a hypothetical mechanism would only be responsible for the probabilities predicted by the quantum theory, and not for a deviation from their value.

So, contrary to Radin et al. statement, that their " results appear to be consistent with a consciousness-related interpretation of the quantum measurement problem," it is in fact the opposite which is true: their results, if correct, would actually disprove such an interpretation, as the consciousness collapse interpretation doesn't contemplate the possibility for the consciousness to alter the probabilities predicted by the projection postulate, but just to actualize their potentiality during an experiment, in accordance with the statistical predictions of the theory. In other terms, the results of Radin et al. speak of something different than quantum mechanics: of a possible radical addition to the laws governing our physical reality.

Of course, one could simply say that, for as long as there is a gap in the theory allowing for a mind-matter interaction of some sort, then one can try to modify the theory in order to allow for the description of these deviations from the quantum statistics, in PK-experiments like those conducted in [1]. This is what some authors try to do, in order to explain the ability of a human observer to select preferred outcomes. I'm certainly not going to enter here into the details of these models, that have been elaborated over the years, using the psychophysical interpretation of the quantum collapse, and other quantum effects (like for instance the quantum Zeno effect, [21]) to try to explain psychokinesis or the mind-brain interaction [22]. What is here important to observe is that independently of their specificities, all these models necessarily have to postulate an additional active mechanism that would be able to guide the collapse, in order for it to deviate from the statistical predictions of quantum theory.

The main point of my note is that all these models are in any case to be considered unfounded, because the psychophysical interpretation is per se baseless. And even if it wouldn't be so, they nevertheless require additional mind-matter interaction mechanisms, beyond the known laws of quantum physics. In that respect, I would like to recall that quantum probabilities are derived in quantum physics from the wave function, and that the wave function is a description of the *state* of a quantum system and the way it reacts when certain experimental actions are performed on it, in a given experimental context. Therefore, to be able to alter the probabilities associated to a quantum measurement one needs either to alter the system itself, or to alter the characteristics of the experimental context (or these two things together). In other terms, to alter the quantum probabilities one needs to change something in a very substantial sense, either in the system or in the measuring apparatus, and this of course, until proven to the contrary, requires *energy*. And such a process of energy transfer, however subtle it might be, certainly cannot be described by means of the mere collapse of the wave function.

What I'm here trying to say is the following: there are no doubts that the reality "out there" is not totally independent from the participatory minds (or consciousnesses) that populate it. Minds, as is well known, can act within reality by means of the physical bodies through which they manifest, carrying out actions that can promote both discoveries and creation processes. Every time we drink for example a glass of water, our mind acts on the glass, transferring energy to it, through the mediation of our physical body, and such a process can certainly be described, in a sense, as a genuine psychophysical interaction (at least from the macro-perspective of the subject).

Therefore, the relevant scientific question, which remains open, is not to understand whether or not a mind-matter interaction would be in general possible, as we already know it is, as the glass of water example demonstrates, but to understand if there exist other non-ordinary mediating structures within our reality, in addition to our ordinary physical bodies, that could be acted out by human minds in order to transfer energy and information (although with a very low efficiency) to ordinary physical systems, so as to modify their states, or the states of their environments, thus explaining their possible non standard behavior, as evidenced in experiments like those conducted in [1].

In conclusion, in the present note I tried to explain that the venerable measurement problem of quantum mechanics has been solved some decades ago by the Belgian physicists Diederik Aerts, in his *hidden-measurement approach*, so that quantum mechanics doesn't need any consciousness-based observer effect, but only an instrument-based observer effect [9–11, 13, 14]. There-

fore, in the same way as physics doesn't need to call for such a psychophysical effect to explain the quantum measurement (nor to the highly improbable existence of parallel worlds or others more or less exotic entities), neither parapsychology should appeal to the latter as a possible foundation to the still controversial PK-effect.

This more mature stance will help, I believe, not only to demystify the purely physical quantum measurement process, but also to possibly shed more light (both in theoretical and experimental terms) on the still controversial PK-effect, which certainly needs a more intense and systematic investigation, beyond the many cultural and philosophical prejudices.

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